Climate Change in New Jersey: Temperature, Precipitation, Extreme Events and Sea Level

Background

There is good evidence that as a result of increasing atmospheric carbon dioxide (CO_2) and other greenhouse gas emissions from human activities, as well as natural climate variability, the Earth's surface has warmed by over 1.5 degrees Fahrenheit (° F); 0.85 degrees Celsius (°C)) since 1880.[1] These increased temperatures have contributed to an overall increase in precipitation, intensity of weather events, and rise in sea level.[1] Continued greenhouse gas emissions at or above current rates are expected to cause further warming and induce many changes in the global climate system during the 21st century that will very likely be larger than those observed during the 20th century. [1]

Regional assessments predict that the Northeastern United States, including New Jersey, will be especially vulnerable to the impacts of climate change and the potential ecological, economic and public health impacts to New Jersey could be devastating.[2] The U.S. National Climate Assessment presents observed and projected climate changes for the Northeast region, reporting that temperatures in the region increased by almost 2°F (0.16°F per decade) while precipitation increased by over 10% or 5 inches (roughly 0.4 inches per decade) between 1895 and 2011.[3] Sea level rose approximately 12 inches since 1900, exceeding the global average of about 8 inches.[1,3(A)] More than any other region in the U.S., the Northeast has seen a greater recent increase in extreme precipitation.[3] From 1958 to 2010, the region received more than a 70% increase in the amount of precipitation falling in the events that are considered very heavy events (by definition, the heaviest 1% of all daily events).[3] In terms of projected climate change for the mid-century, much of the southern portion of the region (including Maryland and Delaware, and southwestern West Virginia and New Jersey) will experience an increase in the number of days per year with temperatures above 90°F compared to the end of the last century.[3]

Regional impacts are unlikely to be completely avoided, even if measures are taken to further curb emissions, due to the momentum generated by past/current activities.[2] In January 2016, the NJDEP Science Advisory Board's (SAB) Climate and Atmospheric Sciences Standing Committee responded to a series of questions pertaining to which aspects of climate change are considered inevitable and how New Jersey can best adapt.[4] Among the concerns presented by this Committee, sea level rise and the resultant impacts on coastal flooding and coastal erosion were considered among the most significant outcomes of climate change that will require adaptation.

It is anticipated that the frequency and/or intensity of precipitation events will increase or show more variable distribution (temporally and spatially) due to climate change (e.g., increasing precipitation in certain seasons, droughts in other seasons, more extreme occurrences of both, etc.). For example, precipitation (as rain, rather than snow) and runoff are likely to increase in the Northeast in both the winter and spring.[2] According to the State Climatologist, New Jersey is getting wetter.[5] The additional atmospheric moisture contributes to more overall precipitation in some areas, especially in much of the Northeast. Such areas, where total precipitation is expected to increase the most, would also experience the largest increase in heavy precipitation events.[2]

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Observations indicate a transition to more rain and less snow as well as snow pack reductions in the Northeast since 1970.[2] For the Northeast, projections indicate that spring melts may begin up to 14 days earlier under high emissions scenarios.[2] Earlier runoff in the absence of increased precipitation produces lower late-summer stream flows, higher water temperatures, and reduced soil moisture in the summer and fall, which due to less water availability stress human and environmental systems.[2]

Despite a trend toward more precipitation since 1970, the Northeast is seeing longer periods without rainfall during longer growing seasons.[2] The result is a drier growing season, especially during the summer months, when temperatures and evapotranspiration are highest. This summer drying tendency is exacerbated by reduced recharge from spring snowmelt. New Jersey has a comprehensive drought monitoring system which allows assessment of drought conditions on a regular basis.[6] The state has experienced one emergency water supply drought (2001-2002) and six drought watches (2005, 2006, 2010, 2015, 2016 and 2017) over the past 16 years.[6] The most recent water supply drought watch was initiated in July 2016 for the northeastern, northwestern, and central drinking water supply regions in NJ.[6] It is anticipated that droughts lasting up to six months may increase in frequency in the Northeast under a low emissions scenario and will increase under a high emissions scenario.[2]

Sea level rise is documented throughout the world, and it is an indicator of the Earth's heat balance.[7] Although there are local and regional influences on sea level that are not related to climate change (such as geological subsidence which exists in New Jersey), globally, sea level rise occurs due to two main reasons: ice melting on land (leading to increased water volume) and the expansion of the ocean as it warms.

Consistent with the observed trend, sea level rise will lead to more frequent and extensive coastal flooding. By the end of the 21st century, several Northeastern U.S. states will have notable portions of their projected populations at risk of adverse effects from sea level rise.[8] One model estimates that by 2100 approximately 309,000 NJ residents could be impacted as a result of a 0.9 meter rise in sea level and over 827,000 residents impacted by a rise of 1.8 meters based on future population growth estimates.[8] These scenarios would place NJ with the fourth largest projected population at risk of impacts from a 0.9 meter sea level rise, and the fifth largest projected population at risk of impacts from a 1.8 meter sea level rise.[8] Warming ocean waters also have the potential to strengthen storms, with more intense impacts likely to affect the Northeast than those seen during Superstorm Sandy in 2012.[9]

Other factors can also influence regional and local temperature and climate besides greenhouse gas emissions. One significant factor is increasing urbanization. The large expanses of asphalt and concrete associated with urban and suburban sprawl, and the resultant loss of forests, fields and other open space, are exacerbating a warming effect. This effect is especially pronounced in densely populated urban areas, which can exhibit what is called the heat island effect.

As illustrated in the figures and table below, long-term data for New Jersey document an increase in average temperature, precipitation, and sea level that are consistent with observed and predicted global trends.

Status and Trends

Temperature

The Office of the New Jersey State Climatologist at Rutgers University has gathered and quality-checked statewide temperature and precipitation records back to 1895.[10] These data show a statistically significant rise in average statewide temperature over the last 120 years (Kendall Tau = 0.490; $p<0.05$). The departure from normal has also significantly increased over the period indicating that average annual temperatures are consistently greater than the longer-term average. The state mean annual temperature from 1895 to 2017 is shown in Figure 1.

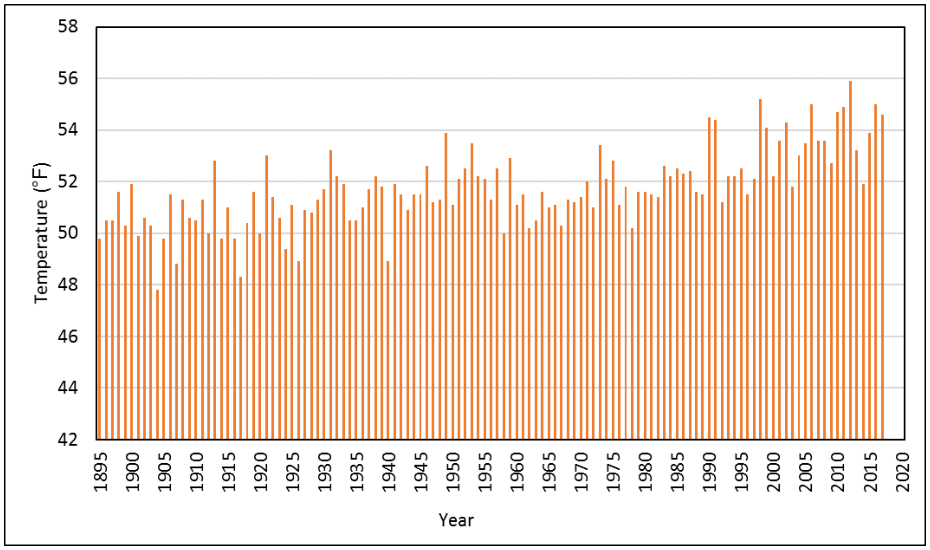

Figure 1: Statewide average annual temperature (1895-2017) [10]

One important aspect of temperature is the effect it has on heating and cooling needs. This effect is often estimated by translating temperature readings into heating degree days or cooling degree days. Heating degree days are a measure of how much (in degrees) and for how long (in days) the outside air temperature was below 65°F, thereby requiring heating. Heating degree days are calculated by multiplying the number of degrees that each day's average temperature is below 65°F by the number of days when the temperature is below 65°F. Cooling degree days are the number of degrees that each day's average temperature is above 65°F, multiplied by the number of days above 65°F. More heating and cooling degree days generally translate to more energy expenditure for heating and cooling, respectively. However, other factors, such as the amount of insulation, the amount of space that is heated or cooled, and the efficiency of the heating or cooling equipment also play a role in heating and cooling energy requirements.

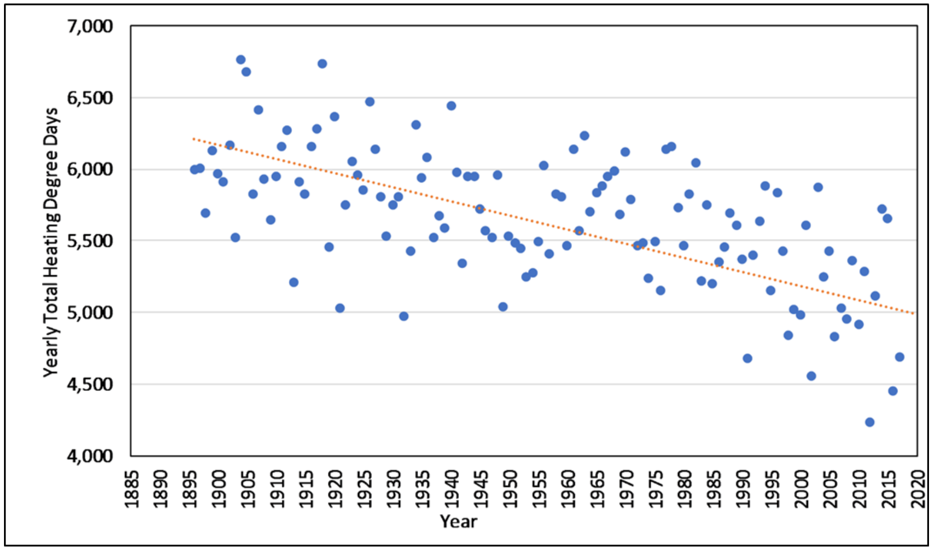

Figure 2: Yearly total heating degree days, NJ; computed from statewide monthly average temperature below 65°F

Yearly total heating and cooling degree days were calculated based on yearly average temperatures for each month for the years between 1895 and 2017, as provided by the State Climatologist (see Figures 2 and 3, respectively). The long-term trend indicates that temperatures have shifted such that relatively fewer days are spent on heating (i.e., warmer temperatures) and relatively more days are spent on cooling (i.e., warmer temperatures). Statistical analysis using Kendall Tau Rank Correlation shows both data sets have significant trends, positive in the case of the cooling degree days (Kendal tau = 0.398, $p < 0.0001$), and negative for the heating degree days (Kendal tau = -0.412, $p < 0.0001$), indicating that both the winters and summers have become warmer in New Jersey during this period.

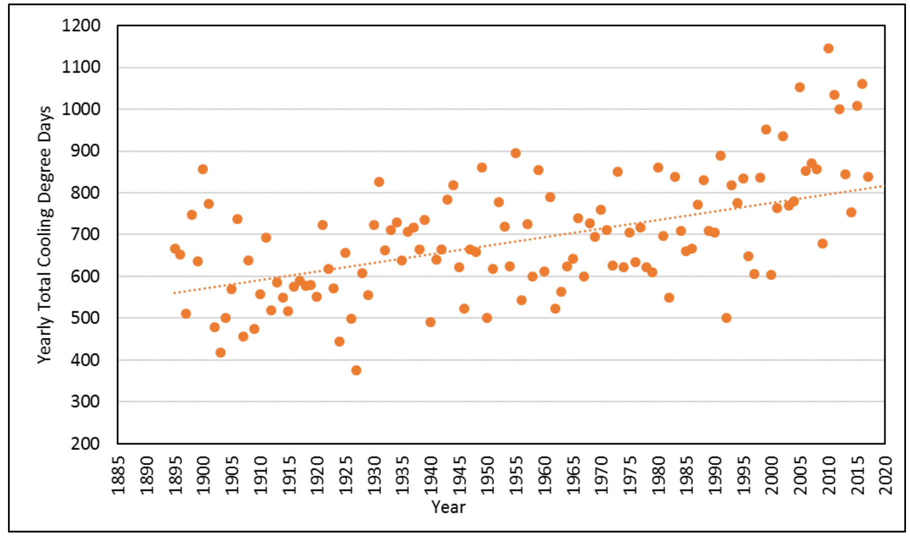

Figure 3: Yearly total cooling degree, NJ; computed from statewide monthly average temperature above 65°F

Precipitation

Total annual precipitation data are also available from the State Climatologist (see Figure 4). Analysis of the data does not show a statistically significant trend since 1895 in total annual precipitation or the departure from normal, but pronounced year-to-year variation is present. To date, 2011 was the wettest year on record. In August of 2011, Tropical Storm Irene dropped more than 16" of precipitation over the state.

Although increased precipitation is projected for New Jersey's future climate, there is considerable uncertainty with respect to the magnitude of change from the baseline as well as the seasonality of the change, which remain active areas of research.

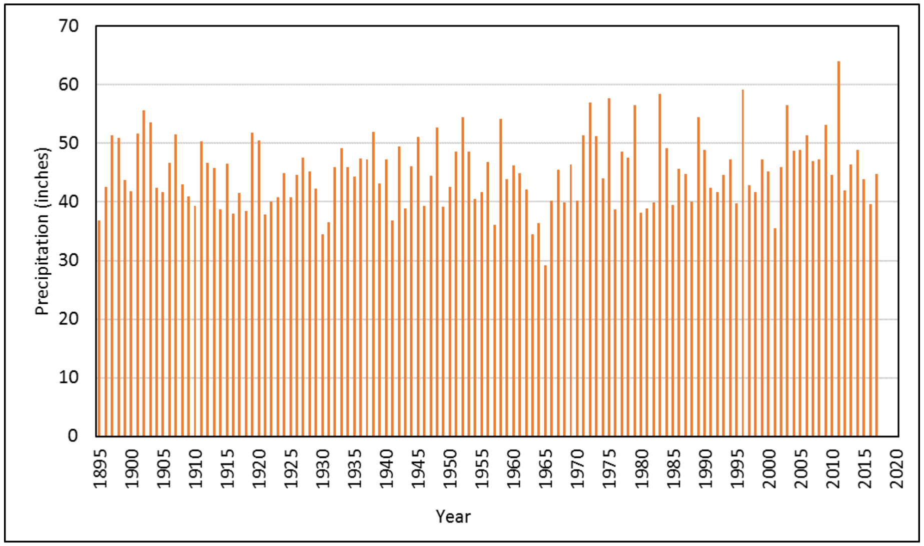

Figure 4: Statewide average annual precipitation (1895-2017). [10]

Extreme Events

A "Climate Extreme" is the occurrence of a weather or climate variable above (or below) a threshold value near the upper (or lower) ends of the range of observed values of that variable.[11] Since 1998, the state has experienced a string of extreme events including Hurricane Sandy, which struck New Jersey in October 2012.[5] It is the most notable in a line of recent weather and climate extremes including:

- Eight of the top ten warmest summers have occurred since 1999 based on the period of 1895 to the present, with 2016 being the fourth hottest summer on record;[12]
- During the 12-month period from October 2015 to September 2016, New Jersey experienced the 9th driest March and its 8th driest August in the last twenty-nine years.[13]
- Four of the top ten snowiest Januarys since 1905 have occurred since 1996.[14]
- Major floods (those that have caused extensive inundation of structures and roads, significant evacuations of people and/or transfer of property to higher elevations[15]) have occurred in New Jersey in recent years, including 2004, 2005, 2006, 2007, 2010, 2011, and 2016.[16]

While increasing variability and extremes are expected in the future, the nature and magnitudes of the extremes still represent an area of great uncertainty.

Sea Level

Tide gauge data made available by the National Oceanic and Atmospheric Administration (NOAA)[17] show that the sea level at the New Jersey coast sites of Atlantic City, Cape May, and Sandy Hook has risen at a rate of approximately 4 millimeters per year (mm/yr) (0.157 in/yr) since recording began in the early- (for Atlantic City and Sandy Hook) to mid-1900s (for Cape May). Recent research completed for the DEP shows that the pre-anthropogenic sea level rise in New Jersey was approximately 2 mm/yr (0.079 in/yr), due to geological factors.[18] This suggests that the anthropogenic contribution to the recent higher rate of rise is approximately 2 mm/yr (0.079 in/yr), approximately one-half of the total observed rate of rise, which is in line with recent estimates of the global rate. Some of the anthropogenic rise is believed to be due to land subsidence caused by groundwater withdrawal and past glacial retreat; with groundwater withdrawal suspected of being especially influential at the Atlantic City site.

Long-term projections of sea level rise (for years 2050 and 2100) for New Jersey from the New Jersey Climate Adaptation Alliance's Science and Technical Advisory Panel (STAP), including estimates based on low and high emissions for 2100, are shown in Table 1.[19] For the central estimates in the table, there is a 50% probability that New Jersey sea level rise will meet or exceed the given values. For the estimates in the likely range, there is a 67% probability that sea level rise will be between the values given in each range. The STAP report recommends that practitioners use a range of estimates due to the array of exposures and vulnerabilities within the state. Sea-level rise estimates for 2050 represent projections under current expectations of fossil-fuel usage. Estimates presented are based on methodologies presented in Kopp et al. (2014).[20]

Additionally, Rutgers University has developed an interactive online mapping tool called NJ Flood Mapper to assist local communities in making decisions concerning flooding hazards and sea level rise.[21]

According to the National Climate Assessment (2014) report, sea level rise of two feet, without any changes in storms, would more than triple the frequency of dangerous coastal flooding throughout most of the Northeast.[2]

Year	Central Estimate	Likely Range
2050	1.4 ft.	1.0 - 1.8 ft.
2100 Low emissions	2.3 ft.	1.7 – 3.1 ft.
2100 High emissions	3.4 ft.	2.4 – 4.5 ft.

Table 1. Sea level rise projections for New Jersey. The baseline is year 2000 sea level.[19]

Outlook and Implications

Rising temperatures are expected to have human health impacts, including increased heat stress,[1] increased levels of ground-level ozone,[22] accelerated secondary fine particle formation,[1] and facilitation of the northern spread of insects carrying arthropod-borne viruses, particularly due to increased temperatures in the winter season.[23]

Heat stress is of special concern for vulnerable urban populations. Climate models predict an increase in the number of days per year with temperatures above 90°F in the New York City metro area, with a potentially significant impact on human health due to heat stress.[24] By the 2020s, climate change could result in a 55% increase in summer heat-related mortality and more than a doubling in mortality by the 2050s.[25]

Natural ecosystems in New Jersey would also be impacted by warmer temperatures and associated changes in the water cycle. These changes could lead to loss of critical habitat, further stresses on some already threatened and endangered species, impacts on water supply, agriculture, and fisheries, more intense rain events, more frequent periods of extended dryness, and continued increases in fires, pests, disease pathogens, and invasive weed species.[26,27]

Sea level rise is a major concern for New Jersey. Sea level in the Northeastern region is projected to rise more than the global average.[25] The state is especially vulnerable to significant impacts due to geologic subsidence, the topography of its coastline, current coastal erosion, and a high density of coastal development.[28] A sea level rise in line with median projections would threaten much of New Jersey's coastlines. These effects will be magnified during storm events, increasing the severity of storm-related flooding and associated erosion in coastal and bay areas. Atlantic City is predicted to experience floods as severe as those that today happen only once a century, to every year or two by the end of the century.[29] In addition, if measures showing a dramatic increased rate of melting of the Greenland ice sheet[30,31] are substantiated by further data, and if the melting continues at this rate or accelerates further, the rate of sea level rise throughout the world will increase, and the severity and frequency of coastal flooding in New Jersey will be even greater.

A separate issue related to climate change that will impact the state is ocean acidification. The associated risks to NJ's waters and recommendations for mitigation have been explored by the DEP Science Advisory Board's (SAB) Ocean Acidification Working Group.[32] Although the ocean can act as a buffer for some climate change impacts, higher levels of carbon dioxide in the atmosphere ultimately result in increased acidity of ocean waters.[33] In some sea areas of the world there has been a 0.1 unit change in pH,[31] which corresponds to a 30% increase in acidity over levels in the mid-eighteenth century. Increased acidity is expected to affect the variety of marine organisms with shells of calcium carbonate, which will impact indicator-species abundance, and ecosystem species composition.[34]

Given the year to year variability (in the frequency and intensity) of nor'easters and hurricanes and their associated storm surges, tracking over long-time scales is necessary before a statistically significant trend can be documented. A shift away from the usual/familiar patterns of climate variability will be bringing changes in many aspects of climate. While it is quite difficult to attribute one particular extreme event, such as a severe hurricane, to human induced climate change rather than natural climate variability, the increased occurrence of such events may be attributed to changes in climate.

More Information

The NJ DEP has information on climate change indicators and impacts from the Air Quality, Energy & Sustainability Program and Coastal Management Program.

New Jersey temperature and other climate data are available here from the New Jersey State Climatologist. In addition, the New Jersey Climate Adaptation Alliance has compiled a variety of reports specific to the state of New Jersey. Visit here for more information.

For additional information on greenhouse gases and initiatives that are being enacted at the state and federal levels to help mitigate their impacts and encourage renewable energies, see the reports, “Greenhouse Gas Emissions” and “Energy Use and Renewable Energy Sources” in this NJDEP Environmental Trends series.

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